6.0 Understanding Your IWEM Input Values

This section of the *User's Guide* will assist you in understanding the WMU, waste constituent and other fate and transport data that IWEM uses to evaluate whether a liner design is protective.

Broadly speaking, there are three main categories of input values:

- WMU data,
- Waste constituent data, and
- Location-specific climate and hydrogeological data.

A Tier 1 analysis requires only a few key inputs. A Tier 2 analysis, which is designed to provide a more accurate evaluation, requires you to provide additional site-specific input data. Section 6.1 describes basic inputs that are common to both Tier 1 and Tier 2 evaluations. Section 6.2 describes the additional inputs for a Tier 2 evaluation.

The *IWEM Technical Background Document (TBD)* provides additional detail on the Tier 1 and Tier 2 input values. To assist you in cross-referencing the discussion on each input parameter to the corresponding section(s) of the TBD, specific references to the TBD are provided for each IWEM input. The references are indicated pictorially as follows:

Section x.y.z
TBD

6.1 Parameters Common to Both Tier 1 and Tier 2 Evaluations

The common parameters are:

1) WMU type,

2) Constituent(s) of concern that are present in the WMU, and

3) Leachate concentration (in mg/L) of each constituent.

6.1.1 WMU Type

Section 3.1; 4.2.1
TBD

IWEM address four different types of WMUs. Each of the four unit types reflects waste management practices that are likely to occur at industrial Subtitle D facilities. The WMU can be a landfill, a waste pile, a surface impoundment, or a land application unit. The latter is also sometimes called a land treatment unit. Figure 6.1 presents schematic diagrams of the different types of WMU's modeled in IWEM.

Landfill. Landfills are facilities for the final disposal of solid waste on land. IWEM considers closed landfills with an earthen cover and either no-liner, a single clay liner, or a composite, clay-geomembrane liner. IWEM assumes there is no leachate collection system. The release of waste constituents into the soil and ground water underneath the landfill is caused by dissolution and leaching of the constituents due to precipitation which percolates through the landfill. The type of liner that is present controls, to a large extent, the amount of leachate which is released from the unit. Because the landfill is closed, the concentration of the waste constituents will diminish with time due to depletion of landfill wastes. The leachate concentration value that is used as an input is the expected initial leachate concentration when the waste is 'fresh'.

Surface Impoundment. A surface impoundment is a WMU which is designed to hold liquid waste or wastes containing free liquid. Surface impoundments may be either ground level or below ground level flow-through units. They may be unlined, or they may have a single clay liner or a composite clay-geomembrane liner. Release of leachate is driven by the ponding of water in the impoundment, which creates a hydraulic head gradient across the barrier underneath the unit. In Tier 1, IWEM uses a national distribution of values for surface impoundment operational life. In Tier 2, you can enter a site-specific value. The Tier 2 default is 50 years.

Waste Pile. Waste piles are typically used as temporary storage or treatment units for solid wastes. Due to their temporary nature, they will not typically be covered. IWEM does consider liners to be present, similar to landfills. In Tier 1 analyses, IWEM assumes that waste piles have a fixed operational life of 20 years, after which the waste pile is removed. In Tier 2, you can provide a site-specific value for the operational life. The default value is 20 years. After the operational period, IWEM assumes the waste pile is removed.

Land Application Unit. Land application units (or land treatment units) are areas of land receiving regular applications of waste which can be either tilled directly into the soil or sprayed onto the soil and subsequently tilled into the soil. IWEM models the leaching of wastes after they have been tilled with soil.

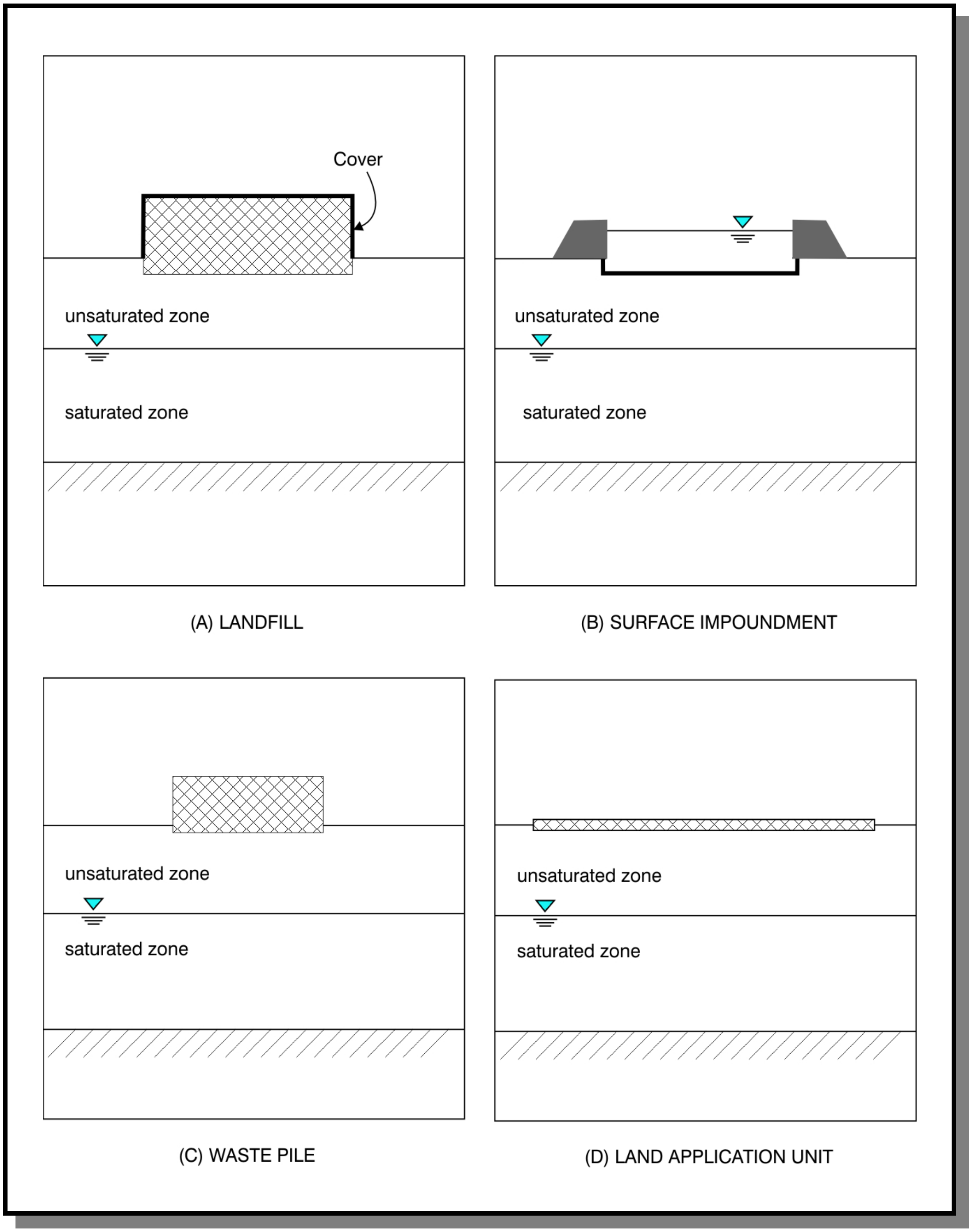

Figure 6.1 WMU Types Modeled in IWEM.

IWEM does not account for the losses due to volatilization during or after waste application. In Tier 1, land application units have a 40 year active life. In Tier 2, you can enter a site-specific value. The Tier 2 default value for operational life is 40 years. Land application units are evaluated for only the no-liner scenarios because liners are not typically used at this type of facility.

6.1.2 Waste Constituents

The IWEM software includes a built-in database with 206 organic constituents and 20 metals. Appendix A provides a list of these constituents. In IWEM you select the waste constituents for each WMU scenario that you wish to evaluate from a drop-down list, either by constituent name or by Chemical Abstract Service (CAS) identification number, or from a list of constituents sorted by constituent name or by CAS number. With each constituent, you also select a set of constituent-specific reference ground-water concentrations (see Section 6.1.4) and fate and transport characteristics. The fate and transport characteristics include sorption parameters and hydrolysis rate constants.

In Tier 1, you can only evaluate constituents found in the built-in database, and you are not able to change the fate and transport characteristic values associated with each constituent. In Tier 2, you can add constituents to IWEM's database as well as modify fate and transport characteristic values for constituents already in the database.

6.1.3 Leachate Concentration

Section 4.2.1.3 TBD

You must provide the leachate concentration in mg/L for each selected waste constituent that you expect in the leachate that will infiltrate into the soil underneath a WMU. EPA has developed a number of tests to measure the leaching potential of different wastes and waste constituents in the laboratory. These include the Toxicity Characteristic Leaching Procedure (TCLP) and the Synthetic Precipitation Leaching Procedure (SPLP). Consult Chapter 2 of the ***Guide*** (Characterizing Waste) for analytical procedures that can be used to determine expected leachate concentrations for waste constituents.

6.1.4 Reference Ground-water Concentrations

Section 5.0 TBD

Associated with each waste constituent is a set of RGCs that reflect not-to-exceed exposure levels for both drinking water ingestion and shower inhalation cancer risks and non-cancer hazards. These include regulatory MCLs and HBNs. Collectively, HBNs and MCLs are referred to in IWEM as RGCs. Each type of RGC is briefly described below.

6.1.4.1 Maximum Contaminant Level (MCL)

Section 5.0 TBD

For a number of constituents, the EPA has set MCLs as part of the National Primary Drinking Water Regulations (NPDWR). The MCL is the maximum permissible level of a contaminant in public water systems. For each contaminant to be regulated, EPA first sets a Maximum Contaminant Level Goal (MCLG) at a level that protects against health risks. EPA then sets each contaminant's MCL as close to its MCLG as feasible, taking costs and available analytical and treatment technologies into consideration.

6.1.4.2 Health-Based Number (HBN)

Section 5.0 TBD

All constituents included in the IWEM software have one or more HBNs. An HBN is the maximum exposure concentration of a contaminant in a domestic water supply that will not cause adverse health effects. Health effects and certain exposure assumptions are considered in the determination of the HBN, while other factors, such as the cost of treatment, are not considered. The HBNs in IWEM are based on the ingestion of drinking water and the inhalation of volatiles during showering. HBN values are based on a target risk of $1x10^{-6}$ for carcinogens and a hazard quotient of 1 for non-carcinogens. HBNs in IWEM were calculated using standard EPA risk assessment assumptions and equations. An overview of the approach used to develop HBNs is given below. Section 5 of the *IWEM Technical Background Document* provides a detailed description.

Ingestion of Drinking Water

Section 5.1 TBD

We calculated ingestion HBNs for a residential receptor who ingests contaminated drinking water for 350 days/year. Consistent with EPA policy, the ingestion HBNs were calculated to reflect consideration of children's exposure. The calculation of cancer HBNs assumed an exposure duration of 30 years and used a time-weighted average drinking water intake rate for individuals aged 0 to 29 years, equal to 0.0252 liters per day per kilogram body weight. In the case of cancer HBNs, the 30-year exposure period represents a high-end (95th percentile) value for population mobility. We chose the 30-year period to cover ages 0-29 to ensure childhood years were included. Non-cancer ingestion HBNs were developed to be protective of children aged 0 to 6 years; the calculations used a daily ingestion rate that is representative of children in this age-group, and is equal to 0.0426 liters per day per kilogram body weight.

Inhalation of Volatiles During Showering **Section 5.2**
TBD

Inhalation HBNs were calculated for adults because we assumed that children take baths. We assumed daily 15 minutes showers for 350 days per year over 30 years and used a shower model to calculate the average constituent concentration in air to which an individual is exposed during a day as a result of volatilization of a constituent in shower water. We assumed that the shower water is ground water from the well modeled by EPACMTP. We also made the important assumption that constituents are released into household air only a result of showering activity, and that exposure to air-phase constituents only occur in the shower stall and bathroom. EPA acknowledges that not considering exposures to children who bathe in bathtubs may be a significant limitation. However, we have not yet developed a "bath" model for evaluating children.

6.1.4.3 Selection of the RGC within the IWEM Software

Tier 1 LCTVs are provided for both MCLs and HBNs. In the case of HBNs, the LCTV reflects the most restrictive pathway and effect, i.e., the lowest of the available HBNs. At Tier 2, you can select the type of RGC (either MCL, ingestion HBN, inhalation HBN, or all) that you wish to use. You may also enter your own constituent-specific RGC values. For example, your state regulatory authority may request that you use HBNs that are calculated using a different target risk level or a different assumption regarding the weight of an adult. (Instructions regarding the selection of RGCs and entering user-specified RGCs are provided in Section 5.4.1.6 of this *User's Guide*.)

6.2 Additional Parameters for a Tier 2 Evaluation

This section describes the additional parameters for which you can provide site-specific values in a Tier 2 evaluation. There are two categories of Tier 2 input parameters: required parameters for which you must provide site-specific values; and optional parameters for which you can provide site-specific values if data are available. When site-specific data for some of the optional model inputs are not available, the suggested default values or distributions of values can be used.

6.2.1 Basis for Using Site-Specific Parameter Values

The Tier 1 evaluation provides a quick screening analysis of whether or not a WMU design is protective for wastes of concern. The IWEM Tier 1 analysis compensates for the lack of site-specific information by being conservative. Tier 1 LCTVs are based on simulating a wide range of conditions, and then selecting the 90^{th} percentile of the predicted ground-water concentration as the basis for assigning the

LCTV. In other words, the Tier 1 evaluation is expected to be protective in 90% of the cases.

The Tier 2 evaluation, which is designed to simulate a specific WMU, has less uncertainty in its liner recommendation than a Tier 1 evaluation of the same site. This reduction in uncertainty is achieved by using site-specific data which are both easily measured and important to the model output.

6.2.2 Tier 2 Parameters

Table 6.1 provides a list of the Tier 2 IWEM parameters. The table indicates: (1) the parameters the user may specify in Tier 2 grouped by the main input groups of the IWEM software, (2) the units of measurement; (3) whether the parameter is a required user input; (4) the IWEM default if the parameter is not a required user input; and (5) the ranges of allowable input values.

Parameters that require user inputs are indicated with **YES** in the corresponding column of the table. All other parameters are optional user inputs. The following sections discuss the Tier 2 parameters in more detail.

6.2.2.1 <u>Tier 2 Parameters that Require User Inputs</u>

Parameters in Table 6.1 that are marked with **YES** in the '*Required User Input?*' column are those for which you must provide a site-specific value in Tier 2; the software does not have a default value. In addition to selecting the WMU type and providing constituent leachate concentrations, there are only four other key parameters for which the user must provide data. They are:

- <u>WMU Area</u>;
- <u>WMU Depth</u> for landfills;
- <u>Ponding Depth</u> for surface impoundments; and
- <u>Climate Center</u> that is nearest to your site.

6.2.2.2 <u>Optional Tier 2 Parameters</u>

Except the required parameters listed above, all other Tier 2 parameters listed in Table 6.1 are optional user input parameters. Use of site-specific data is strongly recommended for these parameters, but if you do not have a value, the IWEM software will allow you to select a default value.

Table 6.1 Tier 2 Parameters

Parameter	Units	Required User Input?	Default	Range	
				Min	Max
WMU Parameters					
WMU Area	m^2	**YES**		1	1.0E+8
WMU Depth (LF only)	m	**YES**		>0	10
Ponding Depth (SI Only)	m	**YES**		0.01	100
Sediment Layer Thickness (SI Only)	m	-	0.2	0.2	100[a)]
WMU Base Depth below ground surface	m	-	0.0	-100[b)]	100[b)]
Operational Life (SI, WP, LAU)	yr	-	(*1*)	1.0	200
Surface Water Body within 2,000 (SI Only)	m	**-**	360	0	5,000
Distance to Ground-Water Well	m	-	150	0	1,609
Subsurface Parameters					
Subsurface Environment	-	-	*(2)*	NA	NA
Depth to Water Table	m	-	*(3)*	0.1	1,000
Saturated Zone Thickness	m	-	*(3)*	0.3	1,000
Hydraulic Gradient	m/m	-	*(3)*	>0	1
Hydraulic Conductivity	m/yr	-	*(3)*	3.15	$1x10^8$
Subsurface pH - Solution limestone environment - All other	-	-	 7.5 6.2	 7 1	 14 14
Infiltration and Recharge Parameters					
Infiltration Rate	m/yr	-	*(4)*	0	100
Nearest Climate Center	-	**YES**	*(5)*	NA	NA
Regional Soil Type	-	-	*(6)*	NA	NA
Waste Type Permeability	-	-	*(6)*	NA	NA
Constituent Parameters					
Constituent Name	-	-	*(7)*	NA	NA
CAS Number	-	-	*(7)*	50-00-0	999999-99-9
K_{oc} (organics only)	L/kg	-	*(7)*	0.0	1.0E+10
Overall Decay Coefficient (organics only)	1/yr	-	*(7)*	0.0	100
Acid Hydrolysis Rate	1/(M·yr)	-	*(7)*	0.0	1.0E+10
Neutral Hydrolysis Rate	1/yr	-	*(7)*	0.0	100

Table 6.1 Tier 2 Input Parameters (continued)

Parameter	Units	Required User Input?	Default	Range	
				Min	Max
Base Hydrolysis Rate	1/(M·yr)	-	*(7)*	0.0	1.0E+10
MCL	mg/L	-	*(7)*	>0	NA
Ingestion HBN - Cancer	mg/L	-	*(7)*	>0	NA
Ingestion HBN - Non Cancer	mg/L	-	*(7)*	>0	NA
Inhalation HBN - Cancer	mg/L	-	*(7)*	>0	NA
Inhalation HBN - Non Cancer	mg/L	-	*(7)*	>0	NA
User RGC	mg/L	-	*(8)*	>0	NA
Exposure Duration	yrs	-	*(9)*	>0	70

NA = Not Applicable
a) Value cannot be larger than impoundment ponding depth
b) Negative value indicates base is above ground surface; depth value cannot be larger than depth to water table.

NOTES:

(1) Default operational life is 50 years for Surface Impoundments, 20 years for Waste Piles, and 40 years for Land Application Units.

(2) Select from the IWEM list; if you select type "unknown," the subsurface parameters will be set to mean values from the IWEM nationwide database.

(3) Assigned from the IWEM database according to the selected subsurface environment.

(4) Assigned from the IWEM database according to the selected climate station, soil type or waste type.

(5) You must select a center from the IWEM list, usually the center nearest to your WMU location.

(6) Select from the IWEM list; if you select type "unknown," the soil type or waste type will be chosen randomly from the three known types during the Tier 2 modeling process.

(7) Applicable only when you wish to add constituents to the IWEM constituent list; you must provide at least one MCL or HBN value for each new constituent.

(8) Applicable when you want to add an HBN to a constituent already in the IWEM database.

(9) Applicable only when you supply a user-specific RGC.

6.2.2.3 Default Values for Missing Data

Default values for Tier 2 parameters are generally obtained from IWEM's internal ground-water modeling and constituent property databases. The IWEM software is designed to help you make reasonable choices for default parameter values. For instance, if you do not know the specific values for ground-water parameters, such as the thickness of the saturated aquifer zone and the hydraulic ground-water gradient, but you do know the general hydrogeology of your site (*e.g.*, you have an alluvial aquifer at your site), IWEM will use this information to select appropriate ground-water values for alluvial aquifers.

Depending on the parameter involved, IWEM may use either a single default value for a missing parameter, or it may use a probability distribution of values, to accommodate a range of possible values.

6.2.2.4 How IWEM Handles Infeasible User Input Parameters

The IWEM software checks all entered data values. It verifies that only numeric data are entered in data fields and that values are non-negative. In addition, IWEM checks that values are all within feasible ranges. When a value is outside the feasible range, IWEM will display a warning and will not allow you to proceed until you change the entered value. Table 6.1 lists the minimum and maximum allowed values for each Tier 2 parameter.

In addition to checking individual parameters, IWEM ensures that combinations of parameters will not lead to physically unrealistic results. This is particularly the case for parameter combinations which could cause an excessive degree of ground-water mounding underneath a WMU. The extent of ground-water mounding depends on WMU characteristics, the permeability of the unsaturated and saturated zones of the aquifer, the depth to ground water and the saturated thickness of the saturated zone. IWEM checks for infeasible parameter combinations after you have entered all Tier 2 parameters and alerts you if it has found a problem. If IWEM determines that the data you have provided will cause an excessive degree of ground-water mounding, IWEM will reduce the allowed infiltration rate.

6.2.3 Tier 2 Parameter Descriptions

This section provides a detailed description of the individual Tier 2 parameters, including how you may obtain site-specific values. The parameters are organized in groups, according to the grouping in the IWEM software data entry screens.

6.2.3.1 WMU Parameters

Sections 3.1, 4.2.1.3, 4.2.5
TBD

WMU Area (m^2). This parameter represents the footprint area of the WMU (area = length x width). This is a required user-input value for a Tier 2 evaluation. The area must be entered in square meters. To convert other units to square meters, use the following factors:

1 Acre	= 4,046.9 m^2
1 Hectare	= 10,000 m^2
1 ft^2	= 0.093 m^2

WMU Depth (m). If you select 'Landfill' as the WMU type, you must also enter the depth of the landfill. This parameter represents the average waste thickness in the landfill at closure. For landfills this is a required user input value. It does not apply to waste piles or land application units. For surface impoundments, you must enter an equivalent parameter, the ponding depth (see below). The landfill depth must be entered in meters. To convert other units to meters, use the following factors:

1 Foot	= 0.305 m
1 Inch	= 0.0254 m

Ponding Depth (m). This is a required user input parameter for surface impoundments only. This parameter represents the average depth of free liquid in the impoundment. Surface impoundments tend to build up a layer of consolidated 'sludge' at their bottom; the thickness of the layer, if present, should **not** be counted as part of the ponding depth. The ponding depth must be entered in meters. To convert other units to meters, use the same conversion factors listed above.

Sediment Layer Thickness (m). This is an optional user input value. It is applicable to surface impoundments only. This parameter represents the average thickness of accumulated sediment ('sludge') deposited on the bottom of the impoundment. The sediment layer thickness must be entered in meters. The default value is 0.2 m. To convert other units to meters, use the same conversion factors listed above.

Depth of the WMU Base Below Ground Surface (m). This is an optional user input value. It represents the depth of the base of the unit below the ground surface, as schematically depicted in Figure 6.2. The depth of the unit below the ground surface reduces the distance in the unsaturated zone through which leachate constituents have to travel before they reach ground water. This depth must be entered in meters. The default value is 0.0 meters, i.e., the base of the unit is level with the ground surface. To convert other units to meters, use the same conversion factors listed above. There may be circumstances in which the base of the WMU is elevated above the ground surface. IWEM can handle this situation in two ways:

a) If you know the depth to ground water of your site, you can enter the total vertical distance between the base of the WMU and the water table as the **Depth of the Water Table** in the subsurface parameters input screen. In this case, set the **Depth of the WMU Base Below Ground Surface** to zero (0.0).

b) If you do not know the depth to the water table, then you can enter the elevation of the WMU base as a **negative** value for the **Depth of the WMU Base Below Ground Surface.** For instance, if the unit is 1 meter above ground surface, enter a value of -1 as the depth.

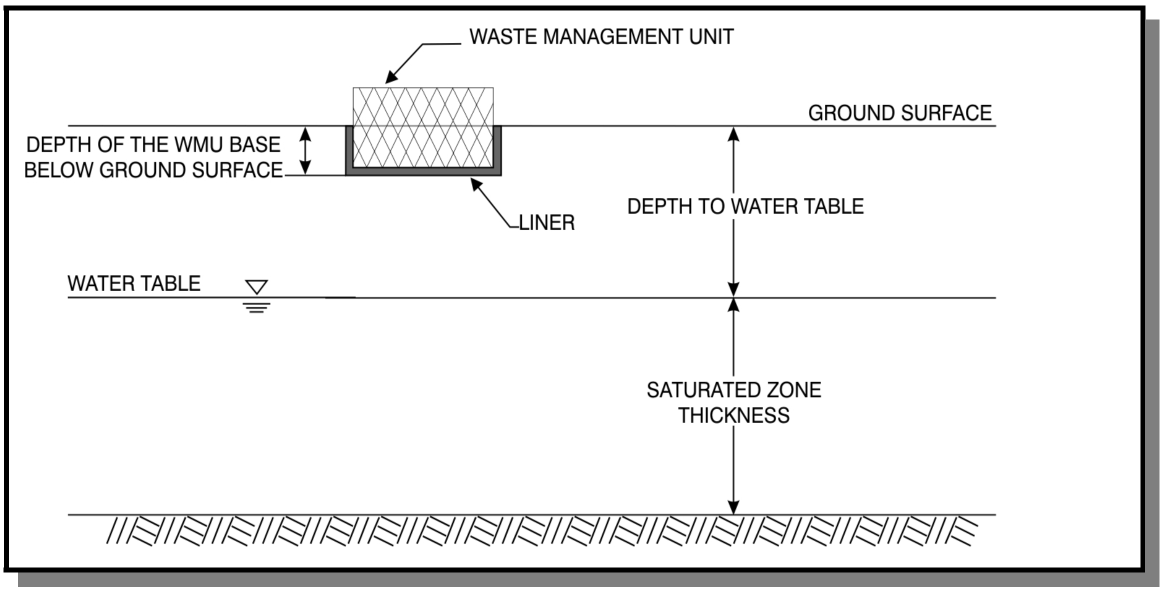

Figure 6.2 WMU with Base Below Ground Surface.

Operational Life (yr). For waste piles, surface impoundments, or land application units, the operational life is an optional Tier 2 user input parameter. This parameter does not apply to landfills because each landfill is assumed closed with waste in place and the time required to deplete the contaminants in a landfill waste is calculated for the user by IWEM. See Section 6.1.1 for more details on leaching durations. The operational life represents the number of years the WMU is in operation, or, more precisely for the purpose of IWEM, the number of years the unit releases leachate. Default values for this parameter are as follows:

- Waste Pile = 20 years
- Land Application Unit = 40 years
- Surface Impoundment = 50 years

Distance to Nearest Surface Water Body (m). For surface impoundments, IWEM needs to know whether or not there is a permanent surface water body within 2,000 meters of the WMU, (*i.e.*, a river, pond, or lake). This parameter is used in the calculation of ground-water mounding to cap the infiltration rate from surface impoundments. The surface water body does not have to be located in the direction of ground-water flow and can be in any direction from the WMU unit. If you know the distance to the nearest surface water body, IWEM will use that value. If the distance is unknown or known with some uncertainty, IWEM provides the following options:

- Distance to surface water body is unknown (IWEM uses 360 m),
- Exact distance is unknown but it is less than 2000 m (IWEM uses 360 m), or
- Exact distance is unknown but it is greater than 2000 m (IWEM uses 5000 m).

Distance to nearest well (m). This parameter represents the distance, in the **direction of downgradient ground-water flow**, to an actual or potential ground-water exposure location. This exposure location can be represented as a ground-water well. Figure 6.3 depicts how the well distance is measured. This figure shows a plan view (upper graph) and a cross-sectional view (lower graph) of a groundwater constituent plume emanating from a WMU. The WMU is represented as the dark rectangular area in the figure. The constituent plume is represented by the lighter shaded area. In this figure, the direction of ground-water flow underneath the WMU is from left to right. The constituent plume follows the direction of ground-water flow, but as it moves, the plume also spreads laterally (upper graph) as well as vertically (lower graph). In IWEM, these processes are modeled by EPACMTP. Figure 6.3 also shows the location of the well.

IWEM always assumes that the well is located along the center line of the plume, but the software randomly varies the depth of the well intake point (see lower graph) during the Monte Carlo simulation process. The distance between WMU and the location of the well is an optional user input parameter at Tier 2. This parameter must be entered in meters, and has a default value of 150 meters (492 feet). To enter a site-specific value, determine the direction of ground-water flow, and then the horizontal distance to the nearest well (or location at which you want to ensure that constituent concentrations in ground water do not exceed protective levels) along the direction of groundwater flow. If you are unsure of the ground water flow direction, it will be protective to enter the shortest distance between the edge of the WMU and the nearest location of concern.

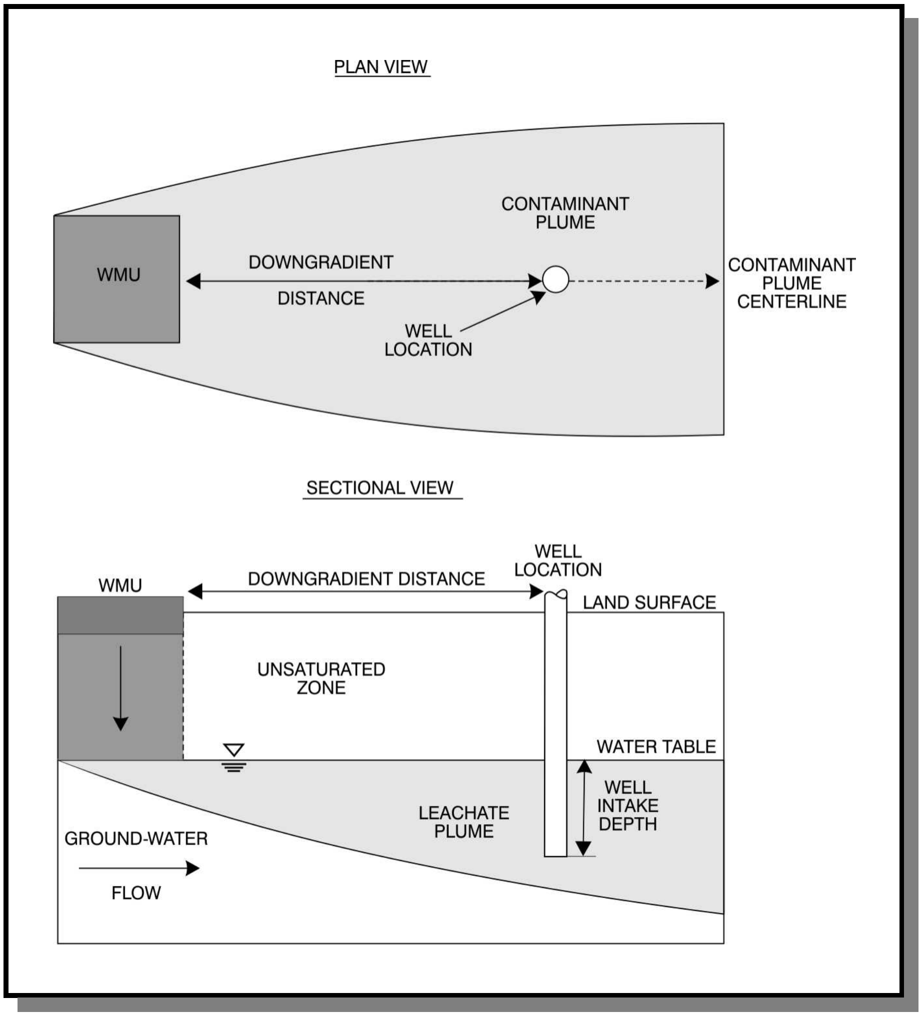

Figure 6.3 Position of the Modeled Well Relative to the Waste Management Unit.

For compatibility with the EPACMTP ground-water model and consistency with related EPA programs, we assume the well is located within 1 mile, or 1,609 meters, from the WMU. IWEM will not accept larger values.

While IWEM allows you to enter a site-specific value for the distance between the well and the WMU, the model does not allow you to modify the depth of the well intake point below the water table. In IWEM evaluations, the depth of the well intake point is always treated as a 'Monte Carlo' parameter, i.e., the tool will vary the well depth during the model simulations, from zero (right at the water table), up to a maximum depth of 10 meters (30 feet) below the water table. If the value for the saturated thickness of your aquifer (see section 6.2.3.2) is less than 10 meters, IWEM will use that actual depth as the maximum value for the well depth. Also, IWEM does not allow you to vary the distance from the center line of the plume.

6.2.3.2 Subsurface Parameters

Section 4.2.3.1
TBD

The subsurface parameters in IWEM comprise a group of the most important ground-water modeling parameters. Unfortunately, these parameters are not easily measured. Obtaining site-specific values for these parameters requires a hydrogeological site characterization. Such information may be available from WMU planning and siting studies, environmental impact assessments, and RCRA permit applications. The United States Geological Survey (www.usgs.gov) and your local state geological survey may also be good sources of site-specific information.

To assist you in performing a Tier 2 evaluation, the IWEM software provides multiple options for entering subsurface parameters to assist you in making the best possible use of information you have. The preferred option is to use accurate site-specific values for all of the parameters, entering them directly in the appropriate data input screens. The second option is where you have values for some, but not all of the parameters. In this case, you enter the parameter values that you know, and IWEM makes a best estimate of the missing values, utilizing knowledge the software has as to how the various parameters tend to be correlated from its national ground-water modeling database. The third, and least desirable, option is where you have no site-specific subsurface data whatsoever. In this case, IWEM simply assigns parameter values that are average values from its database.

The individual IWEM parameters in this group are discussed below.

Subsurface Environments. IWEM includes a built-in database of hydrogeological parameters, organized by 12 different subsurface environments, plus one 'unknown' category, as follows:

1) Metamorphic and Igneous
2) Bedded Sedimentary Rock
3) Till over Sedimentary Rock
4) Sand & Gravel
5) Alluvial Basins, Valleys & Fans
6) River Valleys and Floodplains with Overbank Deposits
7) River Valleys and Floodplains without Overbank Deposits
8) Outwash
9) Till and Till over Outwash
10) Unconsolidated and Consolidated Shallow Aquifers

Subsurface Environment Descriptions

1) Igneous and Metamorphic Rocks
This hydrogeologic environment is underlain by consolidated bedrock of volcanic origin. This hydrogeologic environment setting is typically associated with steep slopes on the sides of mountains, and a thin soil cover. Igneous and metamorphic rocks generally have very low porosities and permeabilities This hydrogeologic environment can occur throughout the United States, but is most prevalent in the western US.

2) Bedded Sedimentary Rock
Sedimentary rock is formed through erosion of bedrock. Deposited layers of eroded material may later be buried and compacted to form sedimentary rock. Generally, the deposition is not continuous but recurrent, and sheets of sediment representing separate events come to form distinct layers of sedimentary rock. Typically, these deposits are very permeable and yield large quantities of ground water. Examples of this hydrogeologic environment setting are found throughout the United States.

3) Till Over Sedimentary Rock
This hydrogeologic environment is found in glaciated regions in the northern United States which are frequently underlain by relatively flat-lying consolidated sedimentary bedrock consisting primarily of sandstone, shale, limestone, and dolomite. The bedrock is overlain by glacial deposits which, consists chiefly of till, a dense unsorted mixture of soil and rock particles deposited directly by ice sheets. Ground water occurs both in the glacial deposits and in the sedimentary bedrock. Till deposits often have low permeability.

4) Sand and Gravel
Sediments are classified into three categories based upon their relative sizes; gravel, consisting of particles that individually may be boulders, cobbles or pebbles; sand, which may be very coarse, coarse, medium, fine or very fine; and mud, which may consist of clay and various size classes of silt. Sand and gravel hydrogeologic environments are very common throughout the United States and frequently overlie consolidated and semi-consolidated sedimentary rocks. Sand and gravel aquifers have very high permeabilities and yield large quantities of ground water.

5) Alluvial Basins, Valleys and Fans
Thick alluvial deposits in basins and valleys bordered by mountains typify this hydrogeologic environment. Alluvium is a general term for clay, silt, sand and gravel that was deposited during comparatively recent geologic time by a stream or other body of running water. The sediments are deposited in the bed of the stream or on its flood plain or delta, or in fan shaped deposits at the base of a mountain slope. Alluvial basins, valleys and fans frequently occupy a region extending from the Puget Sound-Williamette Valley area of Washington and Oregon to west Texas. This region consists of alternating basins or valleys and mountain ranges. The surrounding mountains, and the bedrock beneath the basins, consist of granite and metamorphic rocks. Ground water is obtained mostly from sand and gravel deposits within the alluvium. These deposits are interbedded with finer grained layers of silt and clay.

Subsurface Environment Descriptions (continued)

6) River Alluvium with Overbank Deposits
This hydrogeologic environment is characterized by low to moderate topography and thin to moderately thick sediments of flood-deposited alluvium along portions of a river valley. The alluvium is underlain by either unconsolidated sediments or fractured bedrock of sedimentary or igneous/metamorphic origin. Water is obtained from sand and gravel layers which are interbedded with finer grained alluvial deposits. The alluvium typically serves as a significant source of water. The flood plain is covered by varying thicknesses of fine-grained silt and clay, called overbank deposits. The overbank thickness is usually greater along major streams and thinner along minor streams but typically averages 5 to 10 feet.

7) River Alluvium without Overbank Deposits
This hydrogeologic environment is identical to the River Alluvium with Overbank Deposits environment except that no significant fine-grained floodplain deposits occupy the stream valley. The lack of fine grained deposits may result in significantly higher recharge in areas with ample precipitation.

8) Outwash
Sand and gravel removed or "washed out" from a glacier by streams is termed outwash. This hydrogeologic environment is characterized by moderate to low topography and varying thicknesses of outwash that overlie sequences of fractured bedrock of sedimentary, metamorphic or igneous origin. These sand and gravel outwash deposits typically serve as the principal aquifers within the area. The outwash also serves as a source of regional recharge to the underlying bedrock.

9) Till and Till Over Outwash
This hydrogeologic environment is characterized by low topography and outwash materials that are covered by varying thicknesses of glacial till. The till is principally unsorted sediment which may be interbedded with localized deposits of sand and gravel. Although ground water occurs in both the glacial till and in the underlying outwash, the outwash typically serves as the principal aquifer because the fine grained deposits have been removed by streams. The outwash is in direct hydraulic connection with the glacial till and the glacial till serves as a source of recharge for the underlying outwash.

10) Unconsolidated and Semi-consolidated Shallow Surficial Aquifers
This hydrogeologic environment is characterized by moderately low topographic relief and gently dipping, interbedded unconsolidated and semi-consolidated deposits which consist primarily of sand, silt and clay. Large quantities of water are obtained from the surficial sand and gravel deposits which may be separated from the underlying regional aquifer by a low permeability or confining layer. This confining layer typically "leaks", providing recharge to the deeper zones.

11) Coastal Beaches
This hydrogeologic environment is characterized by low topographic relief, near sea-level elevation and unconsolidated deposits of water-washed sands. The term beach is appropriately applied only to a body of essentially loose sediment. This usually means sand-size particles, but could include gravel. Quartz particles usually predominate. These materials are well sorted, very permeable and have very high potential infiltration rates. These areas are commonly ground-water discharge areas although they can be very susceptible to the intrusion of saltwater.

12) Solution Limestone
Large portions of the central and southeastern United States are underlain by limestones and dolomites in which the fractures have been enlarged by solution. Although ground water occurs in both the surficial deposits and in the underlying bedrock, the limestones and dolomites, which typically contain solution cavities, generally serve as the principal aquifers. This type of hydrogeologic environment is often described as "karst."

13) Unknown Environment
If the subsurface hydrogeological environment is unknown, or it is different from any of the twelve main types used in IWEM, select the subsurface environment as Type 13. In this case, IWEM will assign values of the hydrogeological parameters (depth to groundwater, saturated zone thickness, saturated zone hydraulic conductivity, and saturated zone hydraulic gradient) that are simply national average values.

11) Coastal Beaches
12) Solution Limestone
13) Unknown

This *User's Guide* provides a summary of the geologic and hydrogeologic characteristic of each environment (see text box). You are cautioned that the assignment of a subsurface environment is best done by a professional trained in hydrogeology and is familiar with local site conditions.

Depth to the Water Table (m) This parameter is the vertical distance from the ground surface to the water table as depicted in Figure 6.2. The water table in this case is meant to represent the 'natural' water elevation, as it is or would be without the influence from the WMU. The presence of a WMU, particularly a surface impoundment, may cause a local rise in the water table called mounding. When you run a Tier 2 evaluation, IWEM assumes that the depth to water table value you have entered does not include mounding. The tool will calculate the predicted impact of each liner design on the ground water as part of the modeling evaluation.

If the water table elevation at your site shows seasonal fluctuation, it is best to enter an average annual depth to ground-water value. Note that entering a smaller depth to ground-water value will mean that constituents have less distance to travel before they reach the ground water, and this will tend to result in a more protective IWEM result (*i.e.*, IWEM will tend to predict higher ground-water exposure concentrations and hence return a lower LCTV). It is also important to remember that the depth to ground water should be measured from the ground surface, not from the base of the WMU. If the base of the unit is lower than the ground surface and, therefore, closer to the watertable, you should enter that value as the **Depth of the WMU Base Below the Ground Surface** (see section 6.2.3.1 above).

The depth to ground water should be entered in meters. To convert from other units to meters, use the factors listed in section 6.2.3.1. The default value for this parameter is a function of the selected subsurface environment. If you selected the "unknown" subsurface environment, IWEM will use the national average of 5.2 meters. If you selected one of the twelve subsurface environments and do not specify the depth to the water table, IWEM will treat the depth to the water table as a Monte-Carlo variable: IWEM will use a distribution of values that is appropriate for the selected subsurface environment.

Saturated Zone Thickness (m). This parameter represents the vertical distance from the watertable down to the base of the aquifer, as shown in the diagram in Figure 6.2. Usually the base is an impermeable layer, e.g., bedrock. This parameter is used in the Tier 2 model simulation to describe the thickness of the ground-water zone over which the leachate plume can mix with ground water. If your site has a highly stratified hydrogeology, it may be difficult to precisely define the "base of the aquifer," but in such cases, the stratification may effectively limit the vertical plume travel distance. In this case it may be appropriate to enter the maximum vertical extent of the plume as an "effective" saturated zone thickness in IWEM.

The parameter must be entered in meters. To convert from other units to meters, use the factors given in section 6.2.3.1. The default saturated zone thickness is a function of the selected subsurface environment. If you selected the "unknown" subsurface environment, IWEM will use the national average of 10.1 meters. If you selected one of the twelve subsurface environments and did not specify the saturated thickness, IWEM will treat the depth to the saturated thickness as a Monte-Carlo variable and use a distribution of values that is appropriate for the selected subsurface environment.

<u>Hydraulic Gradient (m/m)</u>. For unconfined aquifers, the hydraulic gradient is simply the slope of the water table in a particular direction. It is calculated as the difference in the elevation of the water table measured at two locations divided by the distance between the two locations. In IWEM, this parameter represents the average horizontal ground-water gradient in the vicinity of the WMU location. The gradient is meant to represent the 'natural' ground-water gradient as it is, or would be, without influence from the WMU. The presence of a WMU, particularly a surface impoundment, may cause local mounding of the water table and associated higher local ground-water gradients. When you run a Tier 2 evaluation, IWEM assumes that the gradient value you have entered does not include mounding; rather the software will calculate the predicted impact on the ground water of each liner design as part of the modeling evaluation.

The hydraulic gradient, together with the hydraulic conductivity (see below), controls the ground-water flow rate, in accordance with Darcy's Law. The effect of varying ground-water flow rate on contaminant fate and transport is complex. Intuitively, it would seem that factors that increase the ground-water flow rate would cause a higher ground-water exposure level at the receptor well, but this is not always the case. A higher ground-water velocity will cause leachate constituents to arrive at the well location more quickly. For constituents that are subject to degradation in ground water, the shorter travel time will cause the constituents to arrive at the well at higher concentrations as compared to a case of low ground-water velocity and long travel times. On the other hand, a high ground-water flow rate will tend to increase the degree of dilution of the leachate plume, due to mixing and dispersion. This will in turn tend to lower the magnitude of the concentrations reaching the well. The Tier 1 and Tier 2 evaluations are based on the maximum constituent concentrations at the well, rather than how long it might take for the exposure to occur, and therefore a higher ground-water flow rate may result in lower predicted exposure levels at the well.

The hydraulic gradient is a unitless parameter. Its default value depends on the subsurface environment you selected. If you selected the "unknown" environment, IWEM will use a nationwide average value of 0.0057. If you selected one of the twelve subsurface environments and did not specify the hydraulic gradient, IWEM will treat the hydraulic gradient as a Monte-Carlo variable, and it will use a distribution of values that is appropriate for the selected subsurface environment.

<u>Hydraulic Conductivity (m/yr)</u>. This parameter represents the permeability of the saturated aquifer in the horizontal direction. The hydraulic conductivity, together with the hydraulic gradient, controls the ground-water flow rate. For the same reasons as discussed above, assigning a low hydraulic conductivity value will not necessarily result in lower predicted ground-water exposures and higher LCTVs. In a broader sense, it means that siting a WMU in a low permeability aquifer setting is not always more protective than a high permeability setting. Low ground-water velocity means that it will take longer for the exposure to occur, and as a result, there is more opportunity for natural attenuation to degrade contaminants. For long-lived waste constituents, it also means that little dilution of the plume may occur.

The hydraulic conductivity of aquifers is sometimes reported as a transmissivity value, which is usually denoted with the symbol 'T'. Transmissivity is simply the product of hydraulic conductivity and saturated thickness. To back-calculate the hydraulic conductivity, you should divide the transmissivity by the value of the saturated zone thickness. The hydraulic conductivity parameter in IWEM must be entered in meters per year. To convert from other units, use the following factors:

1 meter/second	=	31,536,000 m/yr
1 foot/second	=	9,612,173 m/yr
1 gallon/day/foot^2	=	14.89 m/yr

The default value of hydraulic conductivity in IWEM varies with the subsurface environment you have selected. If you selected the "unknown" subsurface environment, IWEM will use a nationwide average value of 1,890 m/yr. If you selected one of the twelve hydrogeologic environments and the hydraulic conductivity as "unknown," IWEM will treat the hydraulic conductivity as a Monte-Carlo variable, and it will use a distribution of values that is appropriate for the selected subsurface environment.

<u>Subsurface pH</u>. This parameter represents the alkalinity or acidity of the soil and aquifer. The pH is one of the most important subsurface parameters controlling the

mobility of metals. Most metals are more mobile under acidic (low pH) conditions, as compared to neutral or alkaline (pH of 7 or higher) conditions. The pH may also affect the hydrolysis rate of organic constituents; some constituents degrade more rapidly or more slowly as pH varies. The pH of most aquifer systems is slightly acidic, the primary exception being aquifers in solution limestone settings. These may also be referred to as 'karst', 'carbonate' or 'dolomite' aquifers. The ground water in these systems is usually alkaline.

IWEM assumes the subsurface pH value is the same in the unsaturated zone and saturated zone. The default pH value depends on the hydrogeologic environment you selected; if you selected "Solution Limestone" (Subsurface Environment 12), the default pH is 7.5. In all other hydrogeologic environments, the default pH value is 6.2. These default values represent median values from EPA's Data Storage and Retrieval System, National Water Quality Database (STORET). If you do not know the hydrogeologic environment, IWEM will assume that the subsurface environment is of a non-solution-limestone type with the default pH of 6.2.

6.2.3.3 Infiltration and Recharge Parameters

Section 4.2.2
TBD

In IWEM, the infiltration rate is defined as the rate (annual volume divided by WMU area) at which leachate flows from the bottom of the WMU (including any liner) into the unsaturated zone beneath the WMU. Recharge is the regional rate of aquifer recharge outside of the WMU. For landfills, waste piles, and land application units, the infiltration rate is primarily determined by the local climatic conditions, especially annual precipitation, and WMU liner characteristics. For surface impoundments, the infiltration rate from the unit is a function of the surface impoundment ponding depth, liner characteristics, and the presence of a 'sludge' layer at the bottom of the impoundment. The regional recharge rate is a function of the annual precipitation rate, and varies with geographical location and soil type.

The WMU related parameters are entered in IWEM in the *WMU Parameters* group (see Section 6.2.3.1). The location and soil related parameters are entered in the *Infiltration and Recharge Parameters* group. Infiltration rate is among the most sensitive site-specific parameters in an IWEM evaluation, and, therefore, the software gives you the option to provide a site-specific value in Tier 2. The model is usually much less sensitive to recharge rate. IWEM determines the appropriate value for you, as a function of site location and soil type. The specific IWEM parameters in this group are as follows.

Site-specific Infiltration Rate (m/yr). This parameter represents the actual annual volume of leachate, per unit area of the WMU, which flows from the bottom of the WMU into the unsaturated zone underneath the WMU. The performance characteristics of a liner, if present, are among the most important factors controlling the infiltration rate, and therefore, the rate of leachate release. IWEM provides you the option to enter a site-specific infiltration rate to accommodate liner designs that are different from the standard liner designs (*i.e.*, (1) no liner, (2) single clay liner, or (3) composite liner), and to evaluate extreme climatic conditions.

IWEM provides default values for infiltration rate, which are a function of WMU type, liner design, and site location. These values are used in Tier 1 and as defaults in a Tier 2 evaluation. The default infiltration rates used in IWEM for landfills, waste piles, and land application units were developed using the Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et. al., 1994). The infiltration rate from a WMU is difficult to measure directly; if you wish to determine site-specific WMU infiltration rates for use in IWEM, it is recommended to use a model such as HELP to estimate the rates.

The infiltration rate in IWEM must be entered in units of meter/year. To convert from other units, use the following factors:

1 foot/year	=	0.305 m/yr
1 inch/year	=	0.0254 m/yr

<u>Climate Center</u>. IWEM includes a database of infiltration rates and regional recharge rates for 102 climate centers located throughout the United States. To ensure that IWEM will use the most appropriate values (if you choose to let IWEM select a default value), you must select the climate center which is most appropriate for your site. Usually this is the nearest climate center. However, this is not always the case. Especially in coastal and mountain regions, the nearest climate center does not always represent conditions that most closely approximate conditions at your site. You should therefore use your judgment and also consider other adjacent climate centers. In the IWEM software tool, you select the climate center from a drop-down list which can be sorted by City or by State. Figure 6.4 shows the geographic locations of the 102 climate stations in the United States.

<u>Regional Soil Type.</u> In order to assign an appropriate recharge rate, IWEM needs to know the dominant, regional soil type in the vicinity of your site. IWEM provides a selection of three major soil types, which are representative of most soils in the United States:

- Sandy Loam
- Silty Loam
- Silty Clay Loam.

IWEM also allows you to select the soil type "unknown." In that case, IWEM will treat the soil type as a Monte-Carlo variable and randomly select from the three available soil types, in accordance with the relative frequency of occurrence of each type across the United States. By selecting the soil type, IWEM also assigns the soil parameters that are used in the modeling of fate and transport in the unsaturated zone of the aquifer.

<u>Waste Type Permeability</u> This parameter is used only for waste piles. Waste piles are not typically covered and the permeability of the waste itself is a factor in determining the rate of leachate released due to water percolating through the WMU. For waste piles, IWEM recognizes three categories of waste permeability and their associated infiltration rate: high permeability (0.041 cm/sec); moderate permeability (0.0041 cm/sec); and low permeability (0.00005 cm/sec). The waste permeability is correlated with the grain size of the waste material, ranging from coarse to five-grained materials.

If you do not specify the waste type for waste piles, IWEM will default to randomly selecting between the infiltration rates for each of the three waste types in the Tier 2 Monte Carlo process, with each type having equal probability. That is, IWEM will use a uniform probability distribution.

Figure 6.4 Locations of IWEM Climate Stations.

6.2.3.4 Constituent Parameters

Section 5.0

IWEM includes a database of 206 organic constituents and 20 metals. Appendix A provides a list of these constituents and their properties. The database provides the following information for each constituent.

- Descriptive Data: *Name,*
CAS Number
- Physical and Constituent Properties: *Organic Carbon Partition Coefficient (K_{oc})*
Metals sorption isotherm data (k_d)
Hydrolysis Rate Constants
- Reference Ground-water Concentrations: *Maximum Contaminant Level (MCL)*
Health Based Numbers (HBN)

To preserve the integrity of the database, IWEM gives you limited flexibility to modify these data. IWEM does give you the option of specifying an overall constituent decay rate which can include biodegradation, proving a constituent partitioning coefficient (k_d), and specifying one additional RGC to augment the built-in MCL and HBN values.

IWEM allows you to add new constituents to its database and this provides an indirect mechanism to assign different constituent parameter values, by entering a constituent of interest as a 'new' constituent in the database with its own parameter values.

The following sections discuss the IWEM constituent parameters.

Descriptive Data

Constituent Name and CAS Number. These parameters are used in IWEM to identify each constituent. Whereas constituents may have multiple names, the CAS number is an industry-standard, unique, identification code. If you want to use the "Add New Constituent" option to assign different fate and transport parameters to an existing IWEM constituent, it is recommended to use the actual CAS number and enter a new constituent name.

Physical and Constituent Properties **Section 4.2.4**
TBD

The physical and constituent properties that affect subsurface fate and transport include sorption parameters and degradation parameters.

Organic Carbon Partition Coefficient (K_{oc}). This parameter describes the sorption, or affinity of a constituent to attach itself to soil and aquifer grains. This parameter is applicable to organic constituents which tend to sorb onto the organic matter in soil or in an aquifer. Constituents with high K_{oc} values tend to move more slowly through the soil and ground water. Volatile organics tend to have low K_{oc} values, whereas semi-volatile organics often have high K_{oc} values. K_{oc} values can be obtained from many constituent property handbooks, as well as online databases, (e.g., *Handbook of Environmental Data on Organic Constituents,* Verschueren, 1983). Sometimes, these references provide an *octanol-water partition coefficient* (K_{ow}), rather than a K_{oc} value. K_{ow} and K_{oc} are roughly equivalent parameters. A number of conversion formulas exist to convert K_{ow} values into K_{oc}, and can be found in handbooks on environmental fate data (*e.g.*, Verschueren, 1983; Kollig et. al., 1983). Different conversion formulas exist for different constituents and environmental media, and there is no single formula that is valid for all organic constituents; therefore, they should be used with some caution.

In IWEM, K_{oc} has units of liters/kilogram (L/kg) or, equivalently, milliliters/gram (mL/g).

Metals Isotherm Data. In the case of metals, sorption is expressed in the partition coefficient k_d. IWEM provides a set of k_d values calculated using the MINTEQA2 geoconstituent speciation model for each metal. Rather than using a single k_d value for each metal constituent, IWEM includes multiple sets of k_d values to reflect the impact of variations in ground-water pH and other geochemical conditions. Each set of k_d values is referred to as a *sorption isotherm*. The sorption parameters for metals in IWEM are part of the software's built-in database and they cannot be modified by the user. Further information on how the MINTEQ sorption isotherms were developed can be found in the *IWEM Technical Background Document* and the *EPACMTP Parameters/Data Background Document*.

If you are adding a new constituent to the IWEM database, you can enter a single k_d value to model sorption for the constituent. The k_d must be entered in units of L/kg or, equivalently, mL/g.

Hydrolysis Rate Constants. Hydrolysis refers to the transformation of constituent constituents through reactions with water. For organic constituents, hydrolysis can be one of the main degradation processes that occur in soil and ground water. The hydrolysis rate values that are part of the IWEM database have been compiled by the U.S. EPA Office of Research and Development (Kollig, 1993). For each organic constituent, the database includes three hydrolysis rate constants: an acid-catalyzed rate constant, a neutral rate constant, and a base-catalyzed rate constant.

Biodegradation

Biodegradation can be a significant attenuation process for organic constituents in the subsurface. However, this process is also highly site- and constituent-specific. It is not possible to provide reliable default biodegradation rates to be used in IWEM. Evidence of the significance of biodegradation should be carefully considered in accordance with EPA guidance, such as the OSWER Directive 9200.4-17P on *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites*. A compendium of EPA bioremediation documents is available online at www.epa.gov/ORD/WebPubs/biorem.html.

By default, IWEM does not explicitly take into account biodegradation processes, and the IWEM constituent database does not include biodegradation rates. However, in Tier 2, the IWEM software allows you to add a constituent-specific biodegradation decay coefficient to its database, as part of the constituent properties input group[8]. This decay coefficient has units of 1/yr. The value of the decay coefficient is related to half-life as:

$$\text{Decay Coefficient (1/yr)} = 0.693 / \text{Half-life (yr)}$$

IWEM stores user-defined decay coefficients in its constituent property database. You should, however, be careful in using a decay coefficient value which is appropriate for one site and not appropriate for others.

Reference Ground-Water Concentrations

Section 5.0
TBD

The final set of parameters in the IWEM constituent database is a set of constituent-specific RGCs, comprising MCLs and risk-based HBNs.

The use of these RGCs in IWEM is discussed in Chapter 7 of this *User's Guide*. The derivation of the HBN values is discussed in Section 5 of the *IWEM Technical Background Document*. You cannot change existing RGCs in the IWEM database. You can, however, add a user-specified RGC value for each constituent in the database when selected for a Tier 2 analysis. IWEM imposes no restrictions on user-specified RGCs,

[8] Strictly speaking this decay coefficient can represent any first-order transformation process other than hydrolysis, which is already explicitly considered in IWEM.

other than that they should be expressed in units of mg/L and an exposure duration is provided (in years) that is consistent with the way the RGC was derived.

User-specified RGCs may represent either more or less stringent health-based values, or alternative regulatory standards. IWEM makes no assumptions about user-specified RGCs and, consequently, the software cannot check whether your value is correct or not.

If you wish to add constituents to the IWEM database, you will be required to provide at least one RGC for each new constituent, either a MCL, an ingestion HBN, or an inhalation HBN. Consult the *IWEM Technical Background Document* for details on the derivation of HBN values. This mechanism also provides an indirect way of using modified MCL and/or HBN values for constituents that are already in the database. In this case, you can add the constituent to the database as a 'new' constituent and provide your own HBN values.